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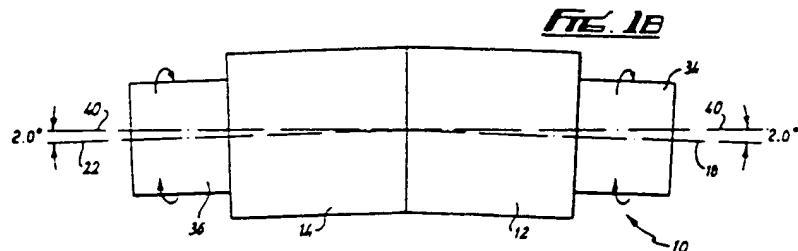
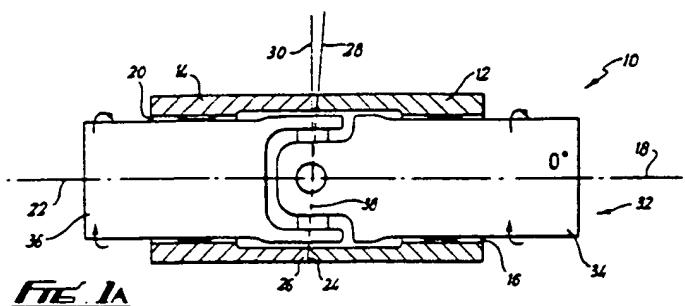
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## (54) Shaft alignment for downhole drilling

(57) A rotary shaft assembly 10 includes a mechanism by which one part 34 of the shaft 32 rotates about a rotation axis 18 which is controllably deviated from the rotation axis 22 of the other part 36 of the shaft 32. The angular extent of deviation (18-40+22-40) is controllably varied by mutually rotating adjacent shaft supports 12,14 about an axis which is at a non-zero angle with respect to both rotation axes. The direction in which the shaft 32 or (132, Fig 2) is deviated is controlled by rotating the non-deviated shaft support (112) with respect to a reference shaft support (150). The assembly (100) includes remote control of direction and deviation. The invention is particularly applicable to drilling of deviated wells. A preferred form of the invention includes a remotely actuated and de-actuated temporary anchoring system (406, Fig 8) for downhole direction sensing and deviation adjustment.



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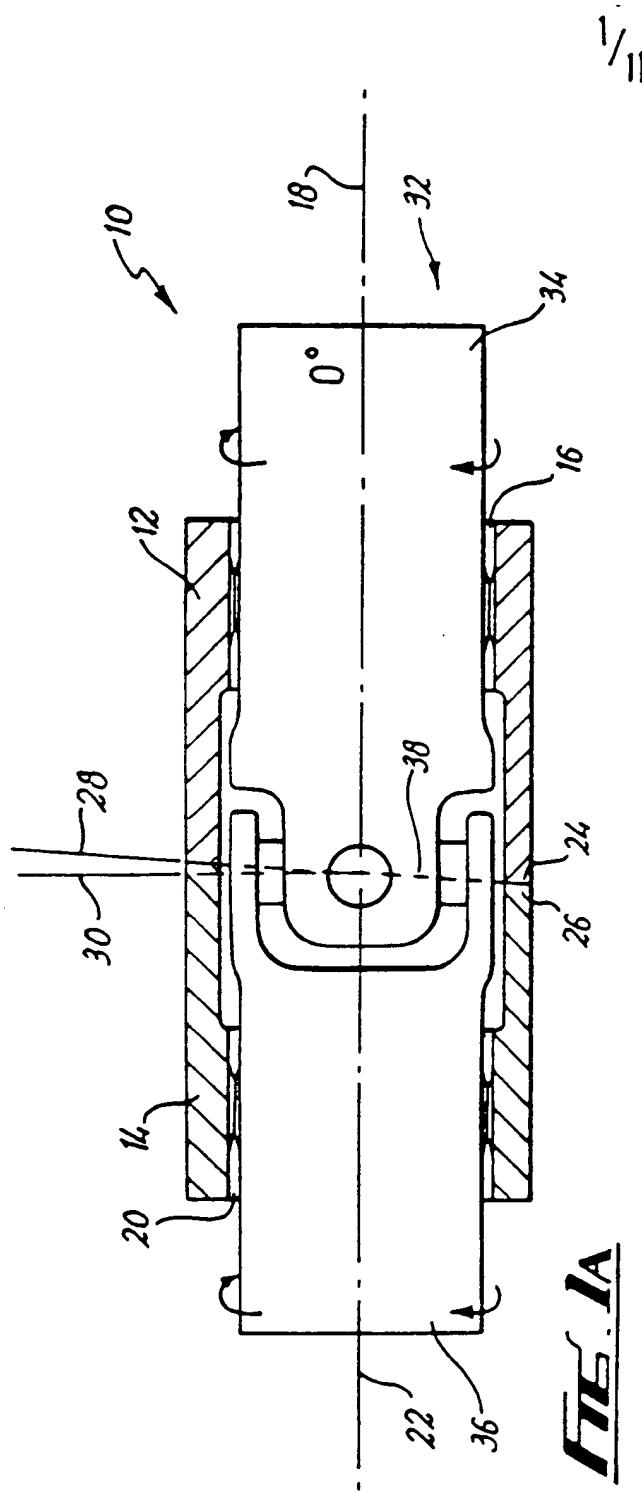
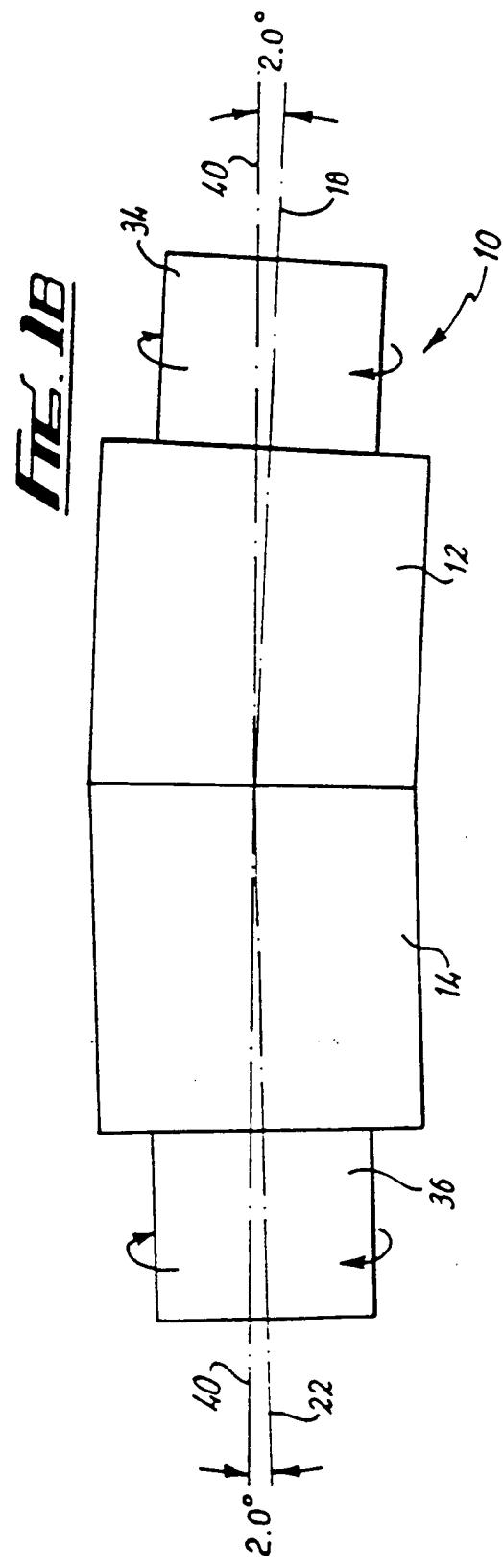
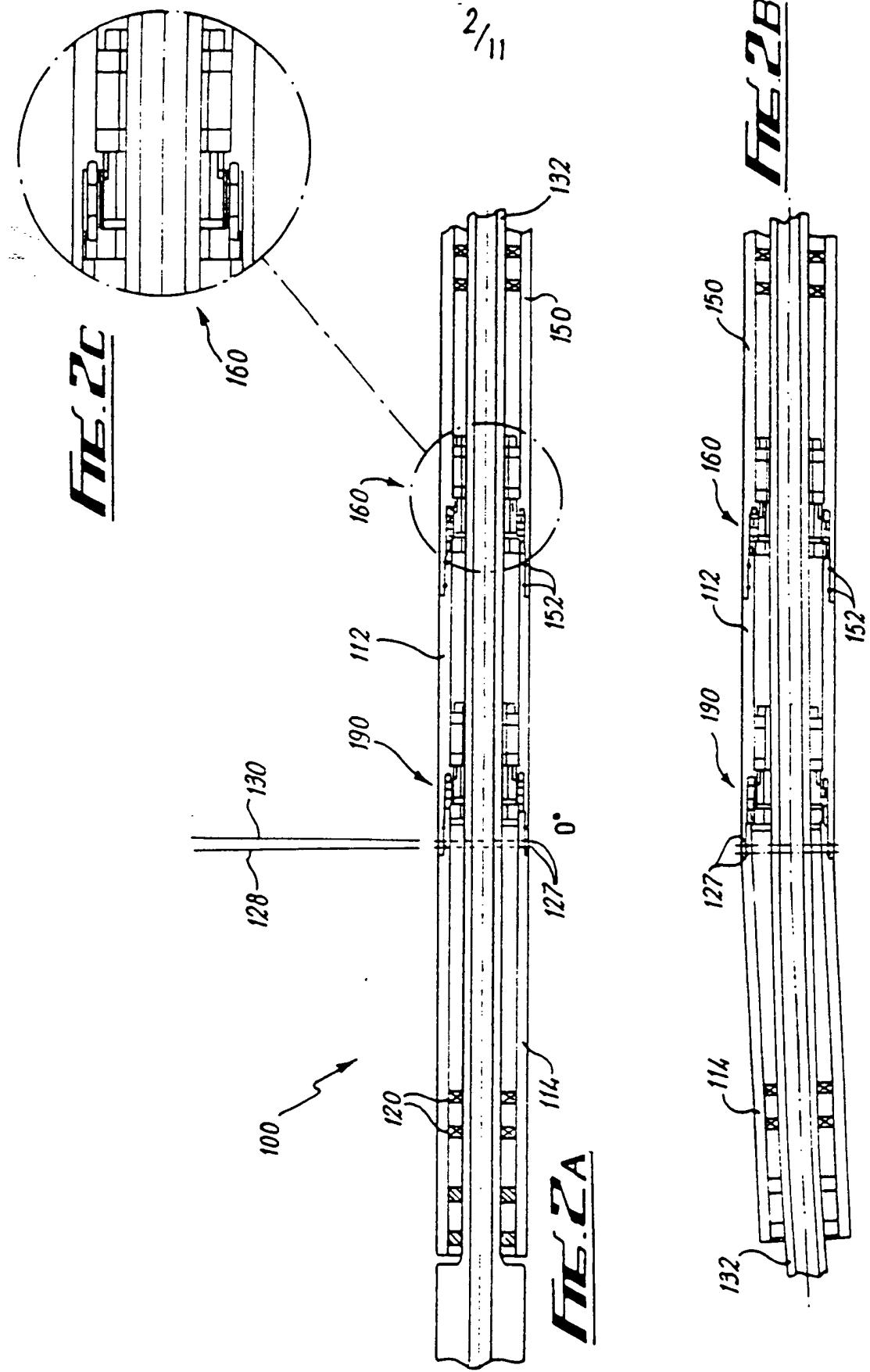


FIG. 1A



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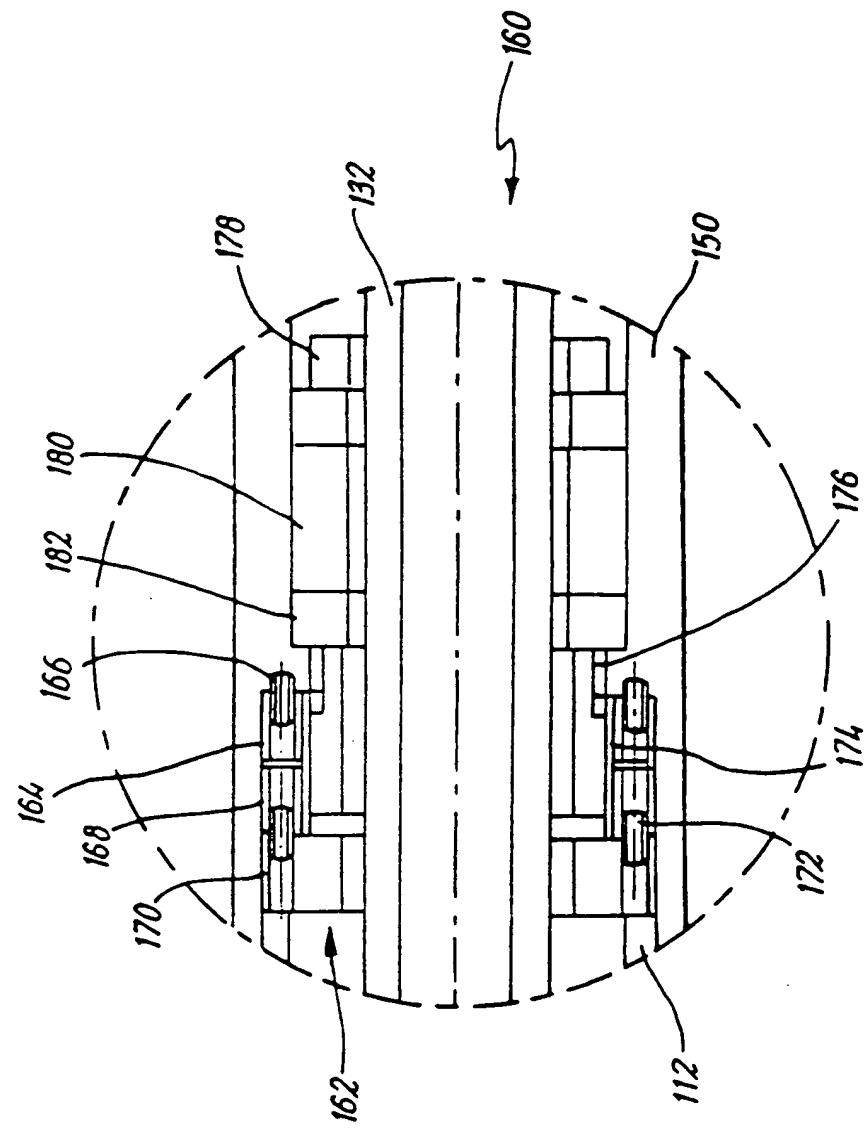
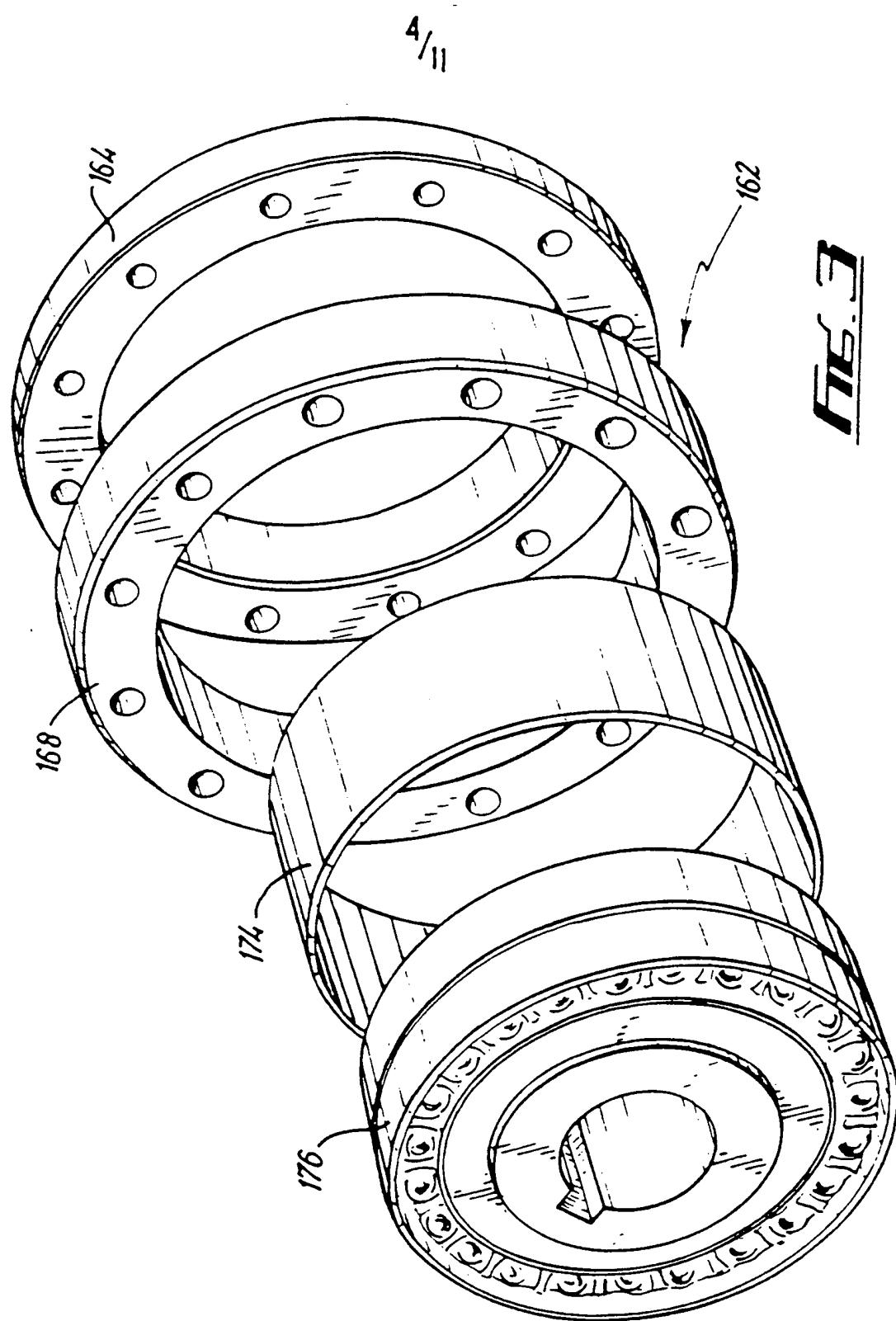
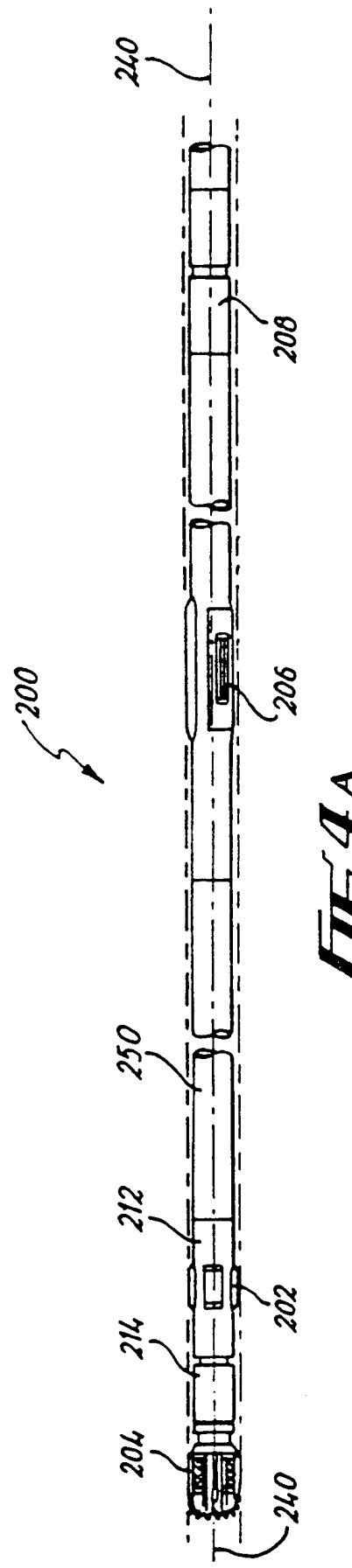


FIG. 2D

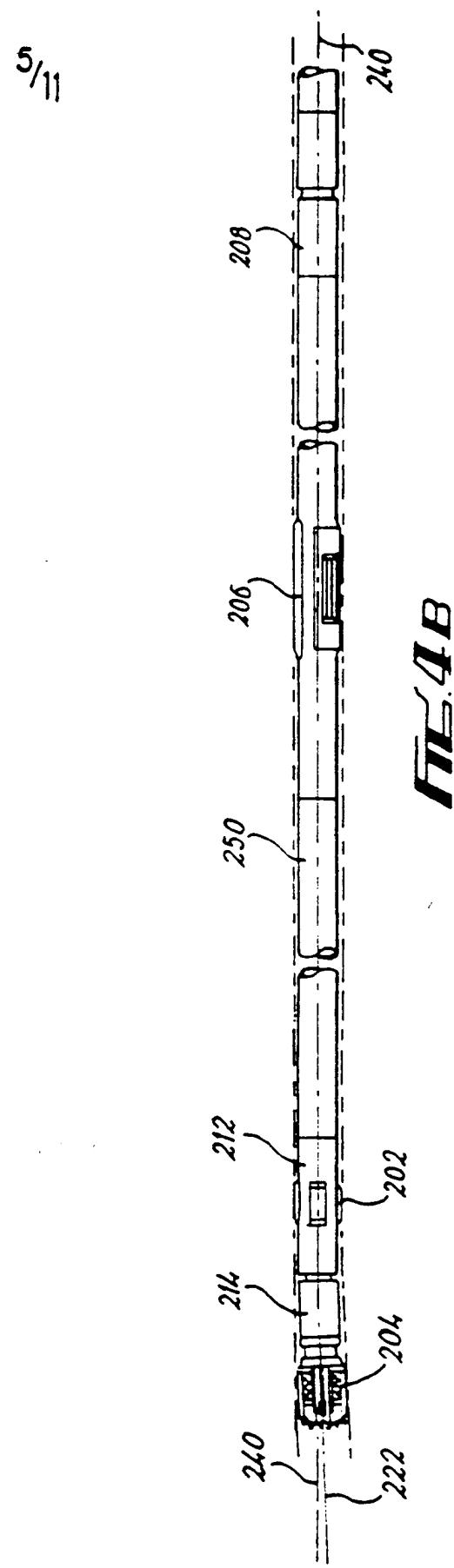
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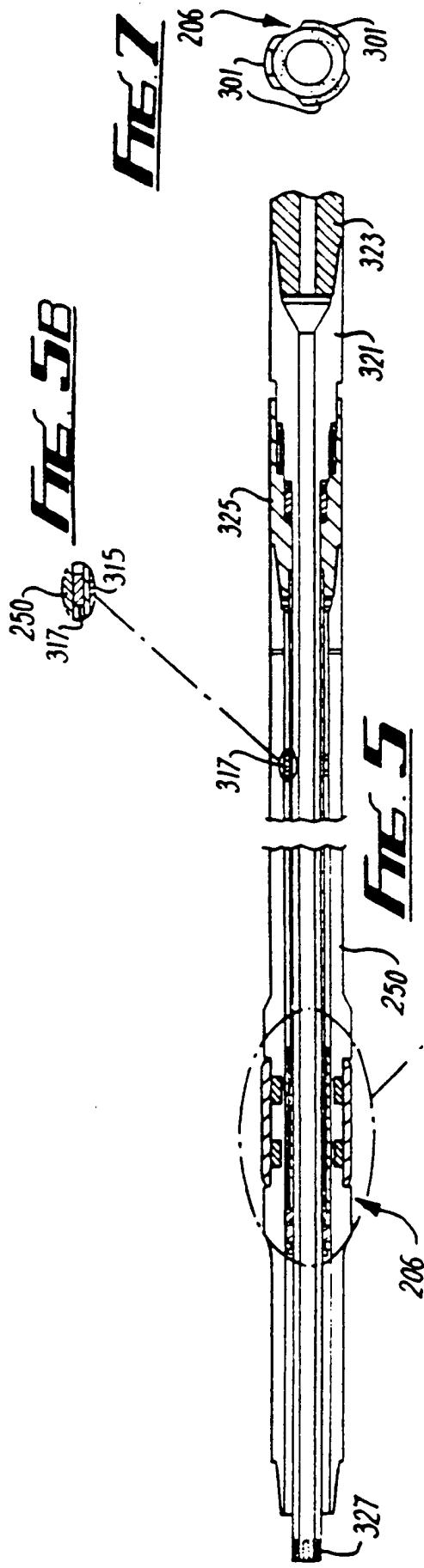
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FIG. 5B



③ FIG. 6

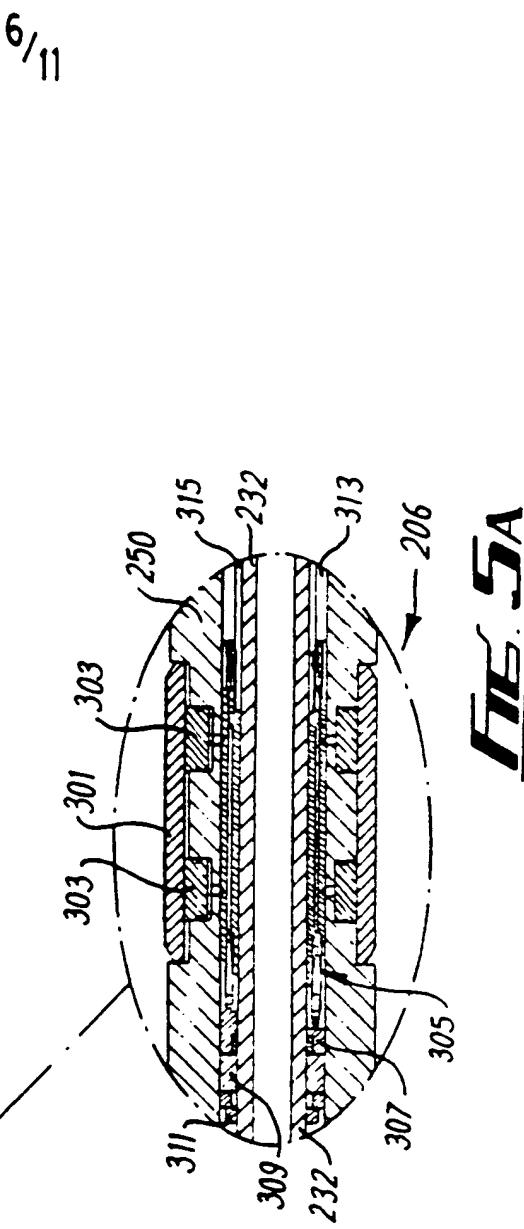
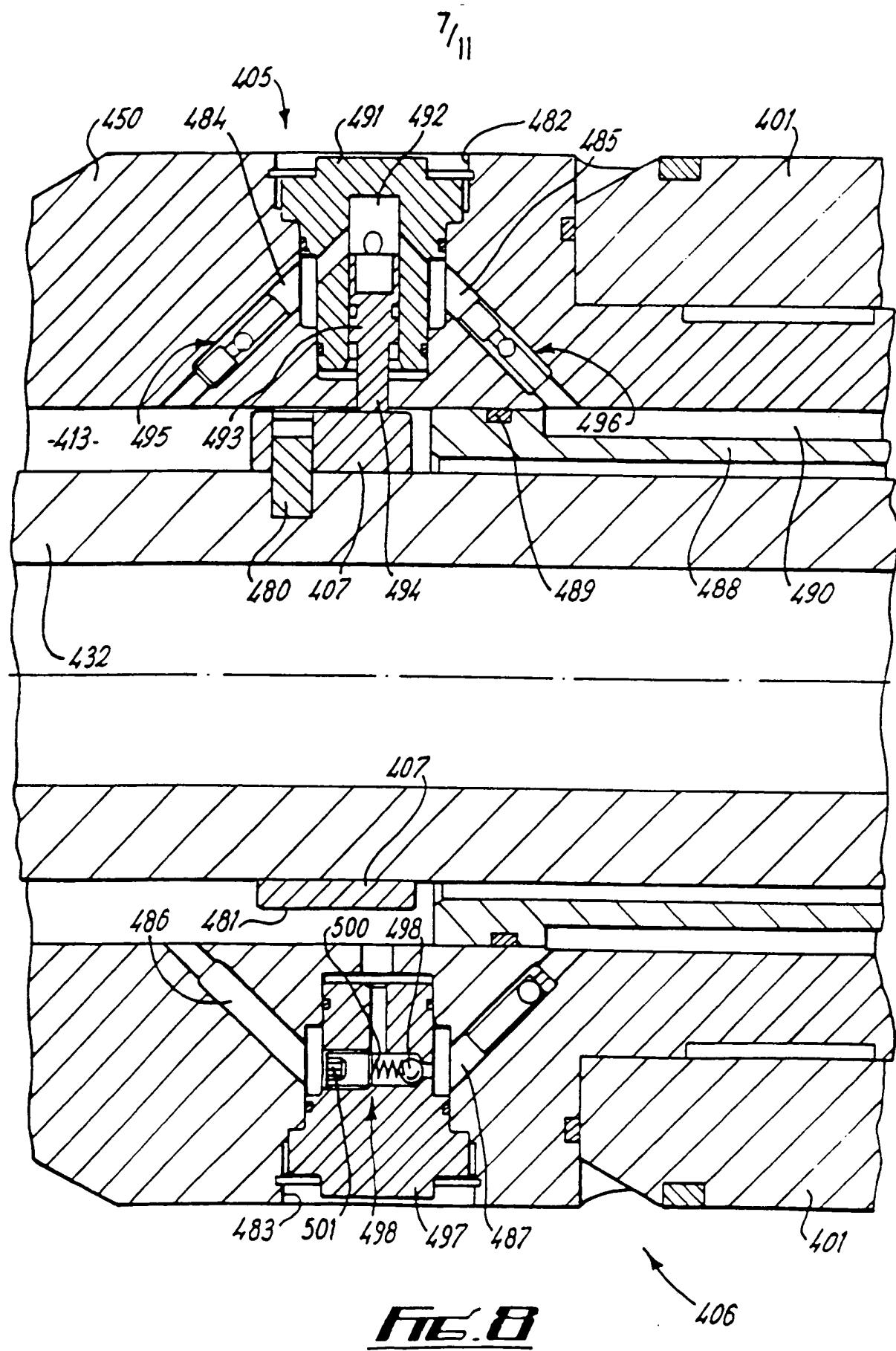


FIG. 5A

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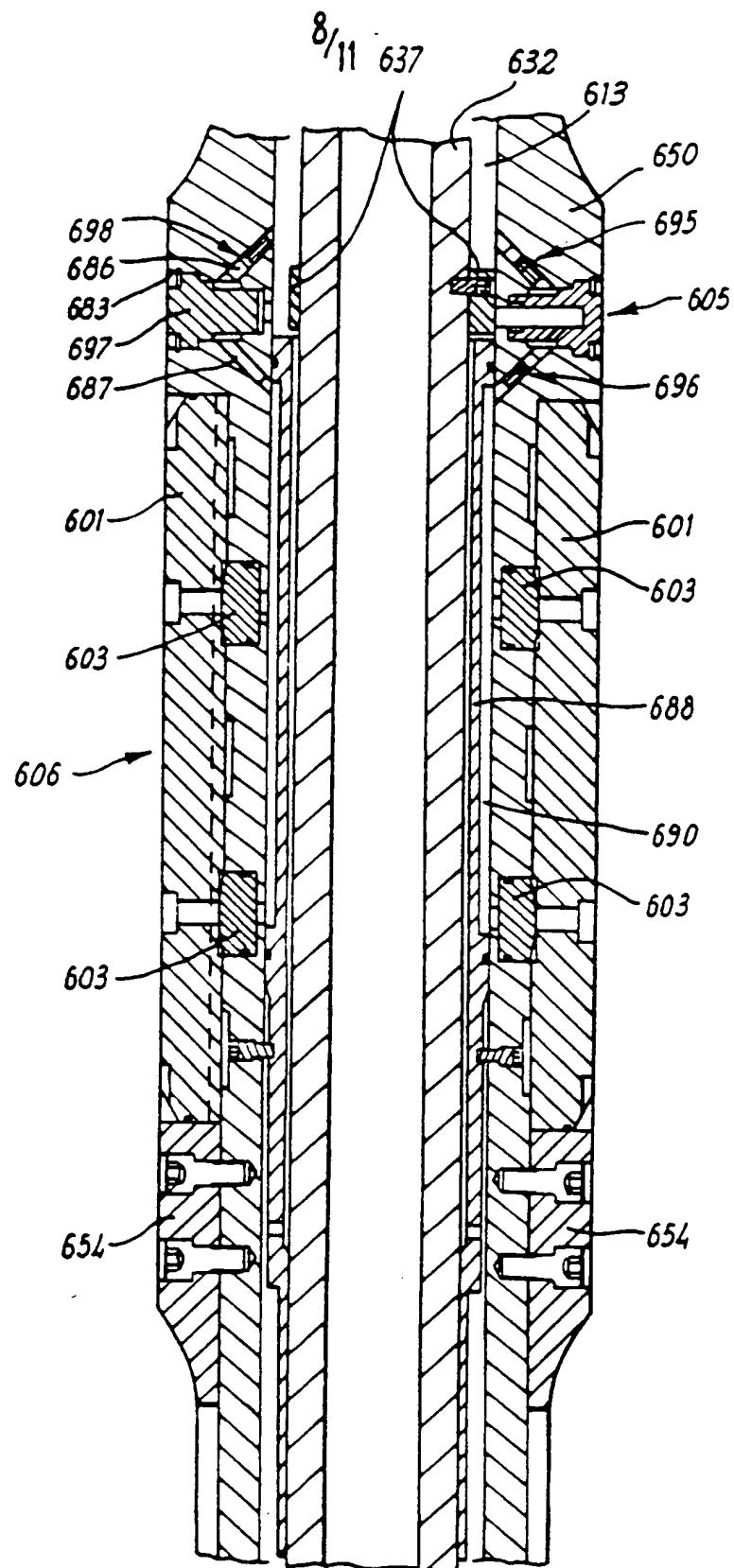


FIG. 9

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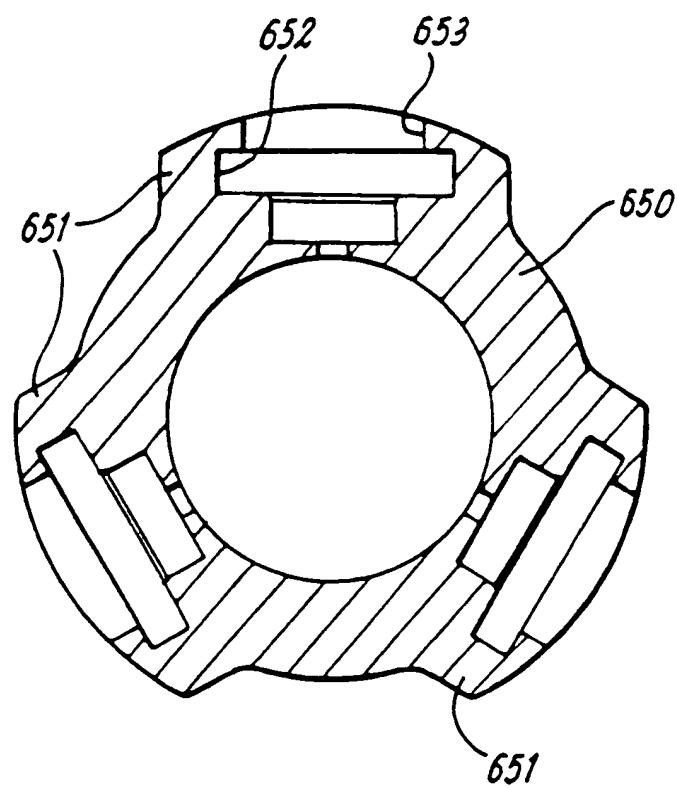


FIG. 10

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600 (part) → 606 → 621  
625  
627 → FIG. 11

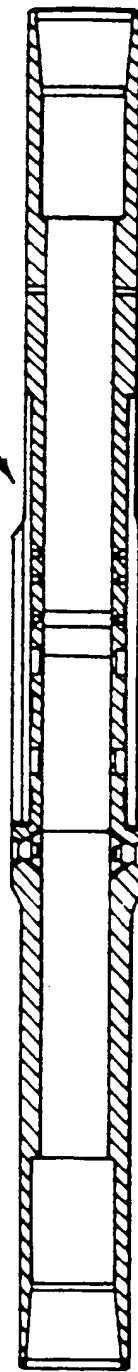


FIG. 12

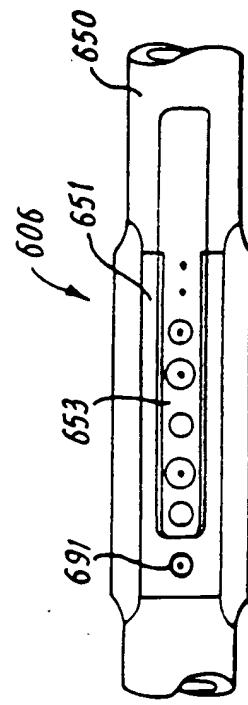


FIG. 13

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FIG. 14A

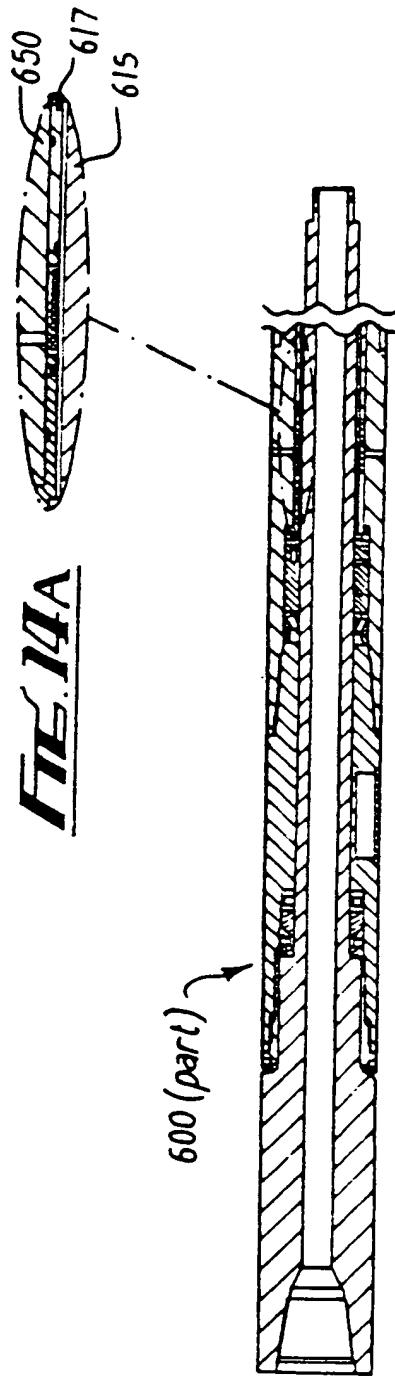


FIG. 14

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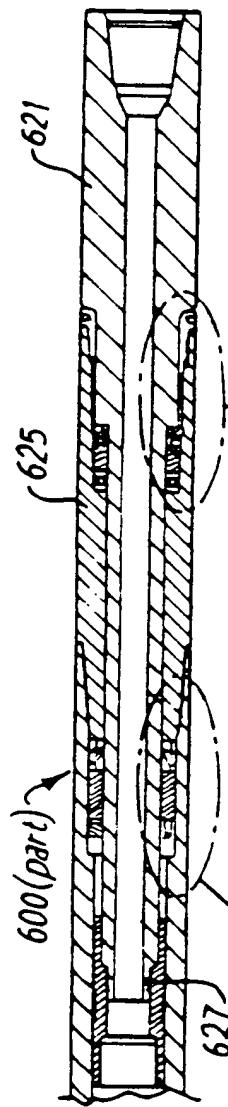


FIG. 15

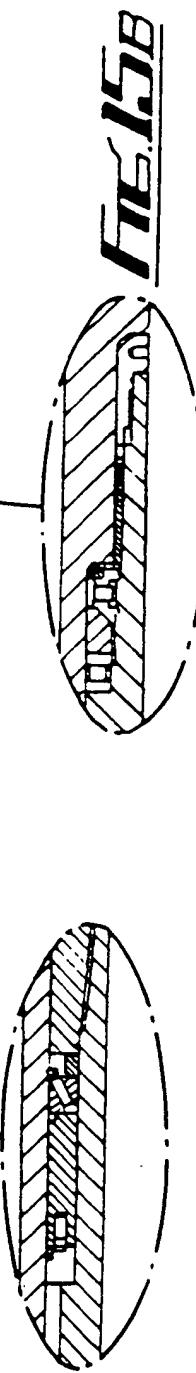


FIG. 15A

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1     "Shaft Alignment"

2  
3     This invention relates to shaft alignment, and relates  
4     more particularly but not exclusively to alignment of  
5     the downhole end of a drillstring for directional  
6     drilling of a well in geological formations.

7  
8     Currently, a large majority of directional drilling is  
9     carried out in the smaller hole sizes, ie 8.5 inches or  
10    less (216 millimetres or less). In recent years,  
11    considerable interest in cost reduction and in  
12    increased productivity from marginal fields has led to  
13    a greater requirement for the drilling of high angle  
14    wells and horizontal wells. Additionally, the  
15    realisation that formation damage had a more  
16    significant effect on productivity than had previously  
17    been appreciated is causing a rapidly expanding  
18    interest in coiled tubing drilling, such that coiled  
19    tubing drilling has now overtaken slim hole drilling in  
20    respect of re-entry well work.

21  
22    Control of direction when drilling is necessary but may  
23    be difficult, particularly in the smaller hole sizes.  
24    Direction control techniques available for larger hole  
25    sizes where the string is nominally rigid and can

1 transmit high torque together with high longitudinal  
2 forces are not available for use in the relatively  
3 small diameter coiled tubing systems where the casings  
4 are flexible and cannot sustain high forces.

5

6 According to the first aspect of the present invention  
7 there is provided a shaft alignment system comprising a  
8 first shaft support means having a first longitudinal  
9 axis and a second shaft support means having a second  
10 longitudinal axis, bearing means rotatably coupling  
11 said first shaft support means to said second shaft  
12 support means, said bearing means having a bearing  
13 rotation axis, said bearing means being arranged with  
14 respect to said first and second shaft support means  
15 such that said bearing rotation axis is aligned at a  
16 first non-zero angle with respect to said first  
17 longitudinal axis and at a second non-zero angle with  
18 respect to said second longitudinal axis whereby  
19 relative rotation of said first and second shaft  
20 support means about their respective longitudinal axes  
21 varies the relative angular alignment of said first and  
22 second longitudinal axes.

23

24 Said first and second shaft support means and said  
25 bearing means are preferably mutually disposed such  
26 that said bearing rotation axis intersects each of said  
27 first and second longitudinal axes, and more preferably  
28 such that said first and second longitudinal axes  
29 mutually intersect.

30

31 Said first and second non-zero angles may be selected  
32 from angles in the range of 1°-3°, and are preferably  
33 mutually equal whereby in one relative rotational  
34 position of the first and second shaft support means  
35 said first and second longitudinal axes are mutually  
36 parallel.

1 Preferably said first shaft support means comprises a  
2 first shaft bearing means for supporting a shaft for  
3 rotation about a first shaft rotation axis coaxial with  
4 said first longitudinal axis in the vicinity of said  
5 first shaft bearing means and said second shaft support  
6 means comprises a second shaft bearing means for  
7 supporting a shaft for rotation about a second shaft  
8 rotation axis coaxial with said second longitudinal  
9 axis in the vicinity of said second shaft bearing  
10 means.

11

12 According to a second aspect of the present invention  
13 there is provided an alignable shaft assembly  
14 comprising the combination of a rotatable shaft means  
15 and the last-preferred form of the shaft alignment  
16 system of the first aspect of the present invention,  
17 said shaft means being rotatably supported by said  
18 first shaft bearing means at a first region along the  
19 length of the shaft means, said shaft means being  
20 rotatably supported by said second shaft bearing means  
21 at a second region along the length of the shaft means,  
22 said shaft means being constructed or adapted for the  
23 transmission of rotation between said first and second  
24 regions in the range of relative alignments of the  
25 first and second shaft support means.

26

27 Said shaft means may be constructed or adapted for the  
28 transmission of rotation between said first and second  
29 regions by being formed as a flexible shaft at least  
30 between said first and second regions, or by the  
31 provision between said first and second regions of a  
32 shaft coupling means mutually coupling said first and  
33 second regions for conjoint rotation. Said shaft  
34 coupling means may be a universal joint, for example a  
35 Hooke joint, or a constant-velocity joint, for example  
36 a Rzeppa joint.

1       In said first and second aspects of the present  
2       invention, the shaft alignment system is preferably  
3       provided with relative rotation control means mutually  
4       coupling said first and second shaft support means for  
5       controllably effecting relative rotation of said first  
6       and second shaft support means. Said relative rotation  
7       control means may comprise non-reversible gear means  
8       mutually coupling said first and second shaft support  
9       means, and controllable drive means coupled to the gear  
10      means for imparting controlled relative rotation to  
11      said first and second shaft support means. As applied  
12      to the second aspect of the present invention, the  
13      controllable drive means may be such as controllably to  
14      tap rotational power from the shaft means, for example,  
15      by way of a controllable clutch. In both aspects of  
16      the invention, the gear means may comprise a harmonic  
17      gearbox.

18  
19      Said first and second aspects of the present invention  
20      preferably further comprise a further support means  
21      having a respective further longitudinal axis, and  
22      further bearing means having a respective further  
23      bearing axis, said further bearing means rotatably  
24      coupling said first shaft support means to said further  
25      support means, said further bearing means being  
26      arranged with respect to said first and further support  
27      means such that said first and further longitudinal  
28      axes are mutually coaxial and also coaxial with said  
29      further bearing axis, whereby controlled rotation of  
30      said first support means with respect to said further  
31      support means results in control of the direction in  
32      which the second longitudinal axis deviates from the  
33      direction of the first longitudinal axis when the  
34      second shaft support means is rotated with respect to  
35      said first shaft support means. A further relative  
36      rotation control means is preferably provided and

1 disposed mutually to couple said first and further  
2 support means for controllably effecting relative  
3 rotation of said first and further support means. Said  
4 further relative rotation control means may be  
5 substantially identical to the first said relative  
6 rotation control means.

7

8 According to a third aspect of the invention there is  
9 provided a directional drilling alignment assembly for  
10 controllably aligning the downhole end of a drillstring  
11 to enable directional drilling of a well in geological  
12 formations, said alignment assembly comprising an  
13 alignable shaft assembly according to the second aspect  
14 of the present invention together with a further  
15 support means as aforesaid, said further support means  
16 being provided with bore anchorage means for  
17 selectively temporarily anchoring said further support  
18 means to a previously drilled bore whereby controlled  
19 rotations of said first shaft support means with  
20 respect to said further support means and of said  
21 second shaft support means with respect to said first  
22 shaft support means enable selective variation (with  
23 respect to said previously drilled bore in which said  
24 further support means is temporarily anchored) of both  
25 the direction (bearing) and angular extent of deviation  
26 of the shaft means in said second shaft support means  
27 and hence of an extension of the bore to be drilled by  
28 a bit on the downhole end of said shaft means.

29

30 Said directional drilling alignment assembly preferably  
31 comprises an azimuth sensor or other direction sensing  
32 means fixed with respect to said further support means  
33 and operative at least when said bore anchorage means  
34 is operative to sense the direction (bearing) of the  
35 further support means when anchored whereby to  
36 determine such further deviation as may be necessary or

1 desirable in order for the drill to proceed in a  
2 particular direction.

3

4 According to the fourth aspect of the present invention  
5 there is provided a method of directional drilling,  
6 said method comprising the steps of providing a  
7 directional drilling alignment assembly according to  
8 the third aspect of the present invention, securing a  
9 drill bit on the remote end of said shaft means and  
10 deploying said alignment assembly on the downhole end  
11 of a drillstring in a previously drilled bore,  
12 temporarily anchoring the further support means of said  
13 alignment assembly in said previously drilled bore,  
14 sensing the direction (bearing) of said temporarily  
15 anchored further support means, rotating said first  
16 shaft support means with respect to said further  
17 support means and/or rotating said second shaft support  
18 means with respect to said first shaft support means  
19 until the rotation axis of the drill bit is aligned in  
20 a selected direction, and continuing drilling.

21

22 Embodiments of the invention will now be described by  
23 way of example with reference to the accompanying  
24 drawings, wherein:-

25

26 Fig 1A is a longitudinal section of a simplified  
27 embodiment of alignable shaft assembly  
28 illustrating the principles of the invention and  
29 configured in an "unbent" condition;

30 Fig 1B is an elevation of the simplified  
31 embodiment of Fig 1A, reconfigured to a "bent"  
32 condition;

33 Fig 2A is a longitudinal section of a preferred  
34 embodiment of alignable shaft assembly, configured  
35 in an "unbent" condition;

36 Fig 2B corresponds to Fig 2A but shows the

1 preferred embodiment reconfigured to a "bent"  
2 condition;  
3 Fig 2C is a fragmentary view of parts of the  
4 preferred embodiment of Fig 2A, to an enlarged  
5 scale;  
6 Fig 2D shows the same view as Fig 2C, to a much  
7 enlarged scale;  
8 Fig 3 is an exploded perspective view, to a much  
9 enlarged scale, of a gearbox employed in the  
10 preferred embodiment;  
11 Fig 4A is a longitudinal view of a preferred  
12 embodiment of directional drilling alignment  
13 assembly, configured in an "unbent" condition;  
14 Fig 4B corresponds to Fig 4A but shows the  
15 assembly reconfigured to a "bent" condition;  
16 Fig 5 is a longitudinal section of a preferred  
17 form of part of the assembly of Fig 4A, to an  
18 enlarged scale;  
19 Fig 5A is a sectional elevation of a fragment of  
20 the assembly part shown in Fig 5, to a much  
21 enlarged scale;  
22 Fig 5B is a sectional elevation of another  
23 fragment of the assembly part shown in Fig 5, to a  
24 much enlarged scale;  
25 Fig 6 is an end elevation of the component at the  
26 left end of the assembly part shown in Fig 5;  
27 Fig 7 is a right end elevation of the assembly  
28 part shown in Fig 5;  
29 Fig 8 is a sectional elevation of an assembly  
30 fragment having a form which is an alternative to  
31 that shown in Fig 5A; and  
32 Fig 9 is a sectional elevation of an assembly  
33 fragment having a form which is a further  
34 alternative to that shown in Fig. 8;  
35 Fig 10 is a transverse cross-section of the  
36 arrangement shown in Fig 9;

1       Fig 11 is a longitudinal section of a directional  
2       drilling alignment assembly incorporating the  
3       arrangement of Fig 9;  
4       Fig 12 is a longitudinal section of the outer part  
5       of the Fig 9 arrangement as incorporated in the  
6       Fig 11 assembly;  
7       Fig 13 is a plan view of part of the Fig 12  
8       arrangement;  
9       Fig 14 is a longitudinal section of the lower  
10      (left) end sub-assembly of the Fig 11 assembly;  
11      Fig 14A is an enlarged view of part of the Fig 14  
12      sub-assembly;  
13      Fig 15 is a longitudinal section of the upper  
14      (right) end sub-assembly of the Fig 11 assembly;  
15      and  
16      Figs 15A and 15B are enlarged views of parts of  
17      the Fig 15 sub-assembly.  
18

19     Referring first to Fig 1A, an alignable shaft assembly  
20    comprises a first shaft support 12 and a second  
21    shaft support 14. The first shaft support 12 is a  
22    hollow tubular component internally fitted with a  
23    rotary beaming 16 which has a rotational axis coaxial  
24    with the longitudinal axis 18 of the first shaft  
25    support 12. The second shaft support 14 is another  
26    hollow tubular component internally fitted with a  
27    respective rotary bearing 20 which has a rotational  
28    axis coaxial with the longitudinal axis 22 of the  
29    second shaft support 14.  
30

31     The first and second shaft supports 12 and 14 abut  
32    along respective end faces 24 and 26.  
33

34     The shaft supports 12 and 14 are mutually rotationally  
35    coupled by a bearing (not shown) which allows relative  
36    rotation between the supports 12 and 14 while keeping

1       their end faces 24 and 26 in mutual contact. The axis  
2       of rotation of this support-coupling bearing is aligned  
3       with a small but non-zero angle to each of the  
4       longitudinal axes 18 and 22. In Fig 1A, this angular  
5       configuration is denoted by the plane 28 of abutment of  
6       the end faces 24 and 26 being at the same small but  
7       non-zero angle with respect to a notional plane 30  
8       which is exactly at right angles to both the  
9       longitudinal axes 18 and 22 (which are coaxial in the  
10      particular configuration of the assembly 10 that is  
11      shown in Fig 1A). In the exemplary arrangement shown  
12      in Fig 1A, the small non-zero angle is 2 degrees.  
13

14      The assembly 10 further includes a shaft 32 comprising  
15      a first shaft section 34 and a second shaft section 36.  
16      The first shaft section 34 is rotatably supported in  
17      the rotary bearing 16 for rotation about a first shaft  
18      rotation axis coaxial with the longitudinal axis 18 of  
19      the first shaft support 12. The second shaft section  
20      36 is rotatably supported in the rotary bearing 20 for  
21      rotation about a second shaft rotation axis coaxial  
22      with the longitudinal axis 22 of the second shaft  
23      support 14. The first and second shaft sections 34 and  
24      36 are mutually coupled for conjoint rotation by means  
25      of a shaft coupling 38 of the type capable of  
26      indefinitely sustained rotation between and  
27      rotationally coupling respective rotary shafts whose  
28      respective rotational axes mutually intersect but which  
29      are non-parallel. As shown in Fig 1A for the purposes  
30      of this simplified explanation of the principles of the  
31      present invention, the shaft coupling 38 is of the type  
32      known as a "universal joint" or Hooke joint (as  
33      commonly employed in cardan shafts, eg the  
34      transmissions of road vehicles which link gearbox to  
35      rear axle). However, for reasons which will  
36      subsequently be explained, the preferred form of the

1 shaft coupling 38 is a coupling of the type shown as a  
2 "constant-velocity joint" (ie a coupling transmitting  
3 rotation without cyclic variations in the angle between  
4 input and output, such as a Rzeppa joint or similar  
5 joints used in the hubs of front-wheel-drive road  
6 vehicles). Alternatively, the shaft 32 could be formed  
7 as a unitary item with a flexible central section  
8 capable of transmitting rotation between ends which are  
9 aligned or variably non-aligned. Additionally, for  
10 further reasons which will also be explained  
11 subsequently, it is preferred that the shaft sections  
12 34 and 36 are hollow and mutually linked by a coupling  
13 38 (of whatever form) which is also hollow to form a  
14 shaft 32 which is capable of carrying pressurised fluid  
15 through the length of the shaft.

16  
17 With the shaft supports 12 and 14 mutually rotationally  
18 aligned as shown in Fig 1A, the respective longitudinal  
19 axes 18 and 22 are mutually coaxial and undeviated, by  
20 reason that the inclinations of the end faces 24 and 26  
21 mutually cancel out (as will subsequently be explained  
22 in greater detail). However, if the shaft supports 12  
23 and 14 are mutually rotated by 180 degrees to the  
24 configuration shown in Fig 1B (with the support-  
25 coupling bearing keeping the inclined end faces 24 and  
26 in mutual contact at all times), the assembly 10  
27 becomes "bent" and each of the longitudinal axes 18 and  
28 22 becomes deviated by 2 degrees with respect to the  
29 rotational centre-line 40. In this "bent"  
30 configuration, the shaft section 36 can still be  
31 rotated by rotation of the shaft section 34 (since the  
32 two shaft sections 34 and 36 are mutually coupled for  
33 conjoint rotation by means of the shaft coupling 38),  
34 but the axis of rotation of the shaft section 36 (which  
35 is, at all times, coaxial with the longitudinal axis 22  
36 of the second shaft support 14) is now deviated by 4

1       degrees from the axis of rotation of the shaft section  
2       34 (which is, at all times, coaxial with the  
3       longitudinal axis 18 of the first shaft support 12).  
4

5       The above-described shaft deviation of 4 degrees is the  
6       maximum that can be achieved with the assembly 10,  
7       wherein the angular deviation of the end faces 24 and  
8       26 with respect to the longitudinal axes 18 and 22 (ie  
9       the angle between planes 28 and 30) is 2 degrees.  
10      Shaft deviations in the range 0 degrees to 4 degrees  
11      can be selected by relatively rotating the shaft  
12      supports 12 and 14 by amounts in the range 0 degrees to  
13      180 degrees. The shaft deviation will vary in cycles  
14      between zero and maximum with each 180 degrees of  
15      support rotation. Different deviation maxima can be  
16      predetermined by forming the assembly with a different  
17      deviation angle in the axis of the support-coupling  
18      bearing.

19

20      The direction in which the shaft section 36 is deviated  
21      with respect to the shaft section 34 can be controlled  
22      by rotating the first shaft support 12 about the  
23      longitudinal axis 18 with respect to a fixed reference  
24      direction (eg North) until the support 12 is suitably  
25      directed, and then rotating the second shaft support 14  
26      about its own longitudinal axis 22 with respect to the  
27      first shaft support 12 until the intended shaft  
28      deviation has accrued, the rotational direction of the  
29      support 12 being such that the support 14 (and the  
30      shaft section 36 rotatably carried by the support 14)  
31      is deviated in the intended direction. Arrangements  
32      for carrying out directional control as well as  
33      deviation control will be described subsequently.

34

35      It should be noted that in normal use of the assembly  
36      10, the shaft supports 12 and 14 will undergo

1 intentional rotation only during changes in deviation  
2 and/or direction, and the shaft supports 12 and 14 will  
3 be static (except for possible longitudinal movement)  
4 whereas the shaft 32 will undergo sustained rotation  
5 (eg for the purpose of well drilling, as will as  
6 exemplified below).

7

8 Referring now to Figs 2A and 2B these show a preferred  
9 embodiment 100 of alignable shaft assembly which  
10 utilises the same general principles as the simplified  
11 embodiment 10 (described above with reference to Figs  
12 1A and 1B) but which includes certain structural  
13 details to produce a more practicable arrangement.  
14 Components and sub-assemblies of the preferred  
15 embodiment of Figs 2A and 2B which are identical or  
16 equivalent to components or sub-assemblies of the  
17 simplified embodiment of Figs 1A and 1B will be given  
18 the same reference numeral but preceded by a "1" (ie  
19 certain of the reference numerals in Figs 2A and 2B are  
20 the corresponding reference numerals from Figs 1A and  
21 1B, plus "100"). The following description of the  
22 preferred embodiment of Figs 2A and 2B will concentrate  
23 on features differing from the simplified embodiment of  
24 Figs 1A and 1B, and hence for a full description of any  
25 part of the preferred embodiment not dealt with below,  
26 reference should be made to the foregoing description  
27 of the identical or equivalent parts of the simplified  
28 embodiment.

29

30 In the preferred embodiment as shown in Figs 2A and 2B  
31 (which correspond in terms of configuration and "bend"  
32 with Figs 1A and 1B respectively), the principal  
33 difference lies in the provision of a further support  
34 150 which is a hollow tubular member that rotationally  
35 supports the first shaft support 112 by means of a  
36 rotary bearing 152. Unlike the bearing (shown as a

1 rotary bearing 127 in this embodiment) which  
2 rotationally couples the second shaft support 114 to  
3 the first shaft support 112, the bearing 152 has a  
4 rotation axis which is coincident with the longitudinal  
5 axes of the supports 112 and 150. This coincidence of  
6 axes ensures that rotation of the support 112 with  
7 respect to the further support 150 does not induce  
8 deviation of the support 112 with respect to the  
9 further support 112.

10

11 The rotation axis of the bearing 127 is deviated by 1 $\frac{1}{2}$   
12 degrees from the longitudinal axes of the supports 112  
13 and 114, such that the maximum shaft deviation in this  
14 preferred embodiment is 3 degrees (see Fig 2B).

15

16 In the embodiment of Figs 2A and 2B, the shaft 132 is a  
17 unitary construct having sufficient flexibility to cope  
18 with the maximum deviation and still have adequate  
19 ability to transmit rotational power. Excessive  
20 curvature of the shaft 132 in its maximum bend  
21 configuration (see Fig 2B) is avoided by omission of  
22 shaft bearings from the support 112.

23

24 By anchoring the further support 150 (eg by use of the  
25 anchoring means subsequently described with reference  
26 to Figs 4A, 4B, 5 and 5A), the support 112 can be  
27 rotated relative to the now-fixed support 150 until a  
28 selected direction is reached, and the support 114 can  
29 be rotated relative to the support 112 until a selected  
30 deviation (in the range 0 degrees to 3 degrees) is  
31 reached.

32

33 The assembly 100 is provided with two sets 160 and 190  
34 of relative rotation control means for respectively  
35 power driving the relative rotation of the support 112  
36 with respect to the support 150, and power driving the

1 relative rotation of the support 114 with respect to  
2 the support 112. The rotation control set 160 couples  
3 the support 112 to the support 150, and is shown in  
4 enlarged detail in Fig 2C. The rotation control set  
5 190 couples the support 114 of the support 112, and is  
6 identical to the set 160 apart from one additional  
7 feature which will be mentioned subsequently.  
8 Accordingly, the following description of the rotation  
9 control set 160 applies also to the set 190 (apart from  
10 the additional feature in the set 190).

11  
12 Reference will now be made to Fig 2D, which is a much-  
13 enlarged version of Fig 2C. The relative rotation  
14 control set 160 comprises a harmonic gearbox 162 of the  
15 type known as "HDUR-IH Size 20" produced by Harmonic  
16 Drive Ltd (GB), and shown separately in Fig 3. An  
17 internally-toothed spline ring 164 is secured to the  
18 further support 150 by means of grub screws 166. An  
19 internally-toothed spline ring 168 is secured to the  
20 support 112, via a drive ring 170, by means of grub  
21 screws 172. The internally-toothed spline rings 164  
22 and 168 have slightly different numbers of teeth, and  
23 are simultaneously engaged by a common flexspline  
24 annulus 174 having external teeth which mesh with the  
25 internal teeth in the rings 164 and 168. The flexspline  
26 annulus 174 is rotated around the inside of the spline  
27 rings 164 and 168 by means of a wave generator 176 in  
28 the form of an eccentric rotated around the common axis  
29 of the gearbox 162. By known techniques this causes  
30 rotation of the spline ring 168 (and hence of the  
31 support 112) relative to the spline ring 164 (and hence  
32 to the support 150) at a rotational rate which is very  
33 much less than the rotational rate of the wave  
34 generator 176, ie the harmonic gearbox 162 has a very  
35 high reduction ratio (typically 160:1).

1 The generally annular form of the harmonic gearbox 162  
2 facilitates its use in the tubular assembly 100, with  
3 the inherent high reduction ratio being particularly  
4 suited to the needs of the assembly 100. In  
5 particular, the shaft 132 can comfortably pass through  
6 the hollow centre of the gearbox 162.

7

8 Power to rotate the wave generator 176 is tapped from  
9 the shaft 132 through an Oldham coupling 178 (to allow  
10 for eccentricity of the shaft 132 which occurs during  
11 "bend" conditions such as are shown in Fig 2B) and  
12 controlled by a clutch/brake unit 180 as dictated by a  
13 rotation sensor 182 coupled to the wave generator 176  
14 to sense its number of revolutions, and hence the  
15 fraction of a revolution by which the support 112 is  
16 correspondingly rotated.

17

18 As already mentioned, the relative rotation control set  
19 190 is the same as the set 160, except that the drive  
20 ring 170 is substituted by a rotation-transmitting  
21 coupling capable of working at deviations up to the  
22 maximum produced by the relative rotation of the  
23 supports 114 and 112 (as produced by operation of the  
24 set 190; see Fig 2).

25

26 The essential components of the harmonic gearbox are  
27 shown in exploded perspective view in Fig 3. In the  
28 gearbox version illustrated in Fig 3, the wave  
29 generator 176 is an eccentric with a bearing-mounted  
30 flexspline-driving periphery; the hub of the eccentric  
31 would be bored out to suit the circumstances of use in  
32 the assembly 100.

33

34 A preferred use of the alignable shaft assembly of the  
35 invention is as a directional drilling system, of which  
36 a preferred embodiment 200 is depicted in Figs 4A and

1       4B (which correspond to Figs 2A and 2B respectively).  
2       The convention for reference numerals used in Figs 4A  
3       and 4B with respect to Figs 2A and 2B is the same as  
4       the convention for reference numerals used in Figs 2A  
5       and 2B with respect to Figs 1A and 1B.

6  
7       Referring to Fig 4A, the support 212 is externally  
8       fitted with an undergauged near-bit stabiliser 202, and  
9       the free end of the shaft 232 is fitted with a drill  
10      bit 204 where it projects from the support 214. The  
11      further support 250 is considerably extended in its  
12      longitudinal direction, and includes a radially  
13      expansible stabiliser 206 operable for temporary  
14      anchoring of the support 250 in order to establish a  
15      stable reference direction for correctly aligning the  
16      support 212, as determined by an azimuth sensor (not  
17      shown) or other suitable instrumentation built-in to  
18      the longitudinally extended support 250. Control  
19      signals can be delivered to the system 200 by way of a  
20      built-in communications link 208.

21  
22      Once the support 212 has been correctly rotated to the  
23      required direction, the support 214 is rotated relative  
24      to the support 212 to produce the required deviation  
25      for further drilling, as depicted in Fig 4B.

26  
27      Parts of the system 200 adjacent to the stabilizer 206  
28      are shown to an enlarged scale in Fig 5 to which  
29      reference will now be made.

30  
31      The stabilizer 206 has three circumferentially  
32      distributed grip pads 301 (shown in end view in Fig 7)  
33      which can be forced radially outwards by pressurising  
34      the undersides of pistons 303 which underlie the pads  
35      301 (more clearly visible in the enlarged fragmentary  
36      view of Fig 5A). Pressurisation for the pistons 303

1 comes from a generally annular axial multi-piston  
2 swashplate pump 305 whose annular swashplate or camring  
3 307 is selectively rotatable under the control of a  
4 clutch 309 which taps power from the shaft 232 by a way  
5 of an Oldham coupling 311. The clutch 309 is operated  
6 when it is required to extend the grip pads 301 to  
7 anchor the stabiliser 206 in the previously drilled  
8 well bore for measurement and possible alteration of  
9 drilling direction. The pump 305 has an oil reservoir  
10 313 defined between an inner sleeve 315 and the inside  
11 of the tubular support 250. The reservoir 313 is  
12 capped by an annular piston 317 (shown enlarged in Fig  
13 5B) which "floats" along the sleeve 315 to provide  
14 pressure compensation.

15  
16 When it is required to de-anchor the stabiliser 206,  
17 the grip pads 301 are retracted by opening the clutch  
18 309 so as to disconnect the pump 305 from the shaft 232  
19 and thereby allow the underside of the pad-extending  
20 pistons 303 to depressurise (either through natural  
21 leakage or through a controlled leak (not shown)  
22 whereupon the pads 301 are "knocked in" by impacts  
23 and/or sustained pressure against the bore, compounded  
24 if necessary or desirable by a suitable arrangement of  
25 springs (not shown) acting on the grip pads 301 to urge  
26 them radially inwards.

27  
28 Fig 5 also shows the <sup>22?</sup> uphole end of the assembly 200,  
29 where the shaft 222 is provided with a connector 321  
30 for attachment to a rotatable drillstring 323. The  
31 connector 321 is rotatably supported on the uphole end  
32 of the support 250 by means of a combined radial and  
33 thrust bearing system 325. The downhole end of the  
34 section of the shaft 232 shown in Fig 5 is formed with  
35 a spline connector 327 for rotational coupling to the  
36 remainder of the shaft 232. The coupling 327 appears

1 at the extreme left of Fig 5, and in end view in Fig 6.

2

3 Referring now to Fig. 8, this shows part of a  
4 stabiliser 406 and its associated hydraulic pump system  
5 405, together constituting an anchoring arrangement  
6 which is an alternative to that shown in Fig 5A. The  
7 reference numerals used in Fig 8 are selected in  
8 accordance with a convention which relates the Fig 8  
9 reference numerals to reference numerals utilised in  
10 preceding Figures in the same manner as the reference  
11 numerals in Figs 4A and 4B relate to the reference  
12 numerals of Figs 2A and 2B, and the reference numerals  
13 of Figs 2A and 2B relate in turn to the reference  
14 numerals of Figs 1A and 1B.

15

16 In Fig 8, only the lower ends of the radially  
17 extensible grip pads 407 are shown, their respective  
18 pistons for inducing outward movement also being  
19 omitted from Fig 8.

20

21 Whereas in the preceding embodiment (Figs 5-7), the  
22 grip pads 301 were set directly into respective  
23 recesses formed in the body of the further support 250,  
24 in the Fig 8 embodiment the grip pads 401 are partly  
25 mounted (at their lower ends) in grip pad retainers  
26 (not shown) screwed onto the exterior of the support  
27 450.

28

29 Also, whereas the pump 305 of the preceding embodiment  
30 was an axial-piston swashplate pump, the pump 405 in  
31 the Fig 8 embodiment is an eccentric-driven radial  
32 piston pump. A hardened steel ring 407 is fitted  
33 around the shaft 432, the ring 407 being keyed to the  
34 shaft 432 by means of a peg 480 radially extending  
35 part-through both ring and shaft. Although the outer  
36 surface of the shaft 432 and the inner diameter of the

1       ring 407 are concentric about the centre-line of the  
2       shaft 432 (ie at a constant radius from the rotation  
3       axis of the shaft 432), the ring 407 has a peripheral  
4       surface 481 which is eccentric to the rotation axis.  
5       In other words, although peripheral surface 481 of the  
6       ring 407 is circular, it is not at a constant radius  
7       from the rotation axis of the shaft 432, and tracing a  
8       circumferential path around the periphery of the ring  
9       407 will involve cyclic variation between a maximum  
10      radial displacement and a minimum radial displacement.  
11  
12      The body of the further support 450 is formed with a  
13      plurality of radially extending through bores 482 and  
14      483 (two of which are visible in Fig 8) which are  
15      circumferentially distributed around the support 450,  
16      and are axially aligned with the ring 407. Side bores  
17      484 and 485 extend both radially and axially from the  
18      bore 482 to intersect the inner surface of the support  
19      450, for a purpose to be detailed subsequently.  
20      Similarly, side bores 486 and 487 extend both radially  
21      and axially from the bore 483 to intersect the inner  
22      surface of the support 450, for a purpose to be  
23      detailed subsequently.  
24  
25      The annular space between the inner surface of the  
26      support 450 and the outer surface of the shaft 432 is  
27      hydraulically divided by a sleeve 488 sealed to the  
28      inner surface of the support 450 by means of an O-ring  
29      489 and other seals (not visible in Fig 8). The volume  
30      490 on the outside of the sleeve 488 forms a gallery  
31      linking the side bores 485 and 487 to the undersides of  
32      the pistons (not shown in Fig 8) which selectively  
33      force the grip pads 401 to extend radially outwards  
34      from the support 450 when anchoring is required. The  
35      volume on the inside of the sleeve 488 is contiguous  
36      with the volume axially below the ring 407 (the left of

1 the ring 407 as viewed in Fig 8) and constitutes the  
2 reservoir 413 holding hydraulic fluid as a supply for  
3 the pump 405 as will now be detailed.

4  
5 A circular plunger housing 491 is mechanically secured  
6 and hydraulically sealed into the bore 482. The  
7 housing 491 has a radially extending central bore 492  
8 holding a reciprocable piston 493 which is slidingly  
9 sealed to the housing bore 492. The radially inner end  
10 494 of the piston 493 extends radially through the  
11 radially inner end of the bore 482 and is held in  
12 contact with the eccentric ring periphery 481 by means  
13 of a coiled compression spring (omitted from Fig 8)  
14 housed in the bore 492 above the radially outer end of  
15 the piston 493. As the shaft 432 rotates relative to  
16 the further support 450, the ring 407 rotates relative  
17 to the plunger housing 491 such that the eccentric  
18 periphery 481 reciprocates the piston 494 within its  
19 housing bore 492.

20  
21 The side bore 484 communicates the reservoir 413 with  
22 the housing bore 492 by way of a one-way valve 495  
23 constituted by a spring-loaded ball arranged such that  
24 the valve 495 functions as an automatic inlet valve for  
25 the piston pump constituted by the combination of the  
26 piston 493 and the bore 492 (the pump being driven by  
27 relative rotation of the ring 407).

28  
29 The side bore 485 communicates the bore 492 with the  
30 pressure gallery 490 leading to the pistons for  
31 extending the grip pads 401, by way of a one-way valve  
32 496 constituted by a spring-loaded ball arranged such  
33 that the valve 496 functions as an automatic outlet  
34 valve for the piston pump constituted by the  
35 combination of the piston 493 and the bore 492.

36

1 A circular housing 497 is mechanically secured and  
2 hydraulically sealed into the bore 493. The housing 493  
3 hydraulically links the pressure gallery 490 to the  
4 reservoir 413 by way of the side bores 487 and 486,  
5 through a housing-mounted pressure-limiting safety  
6 valve 498 constituted by a ball 499 loaded by a spring  
7 500 whose force (and hence the valve's blow-down  
8 pressure) is adjustable by a screw 501. The safety  
9 valve 498 operates to prevent excessive pressurisation  
10 of the gallery 490 by limiting its pressure with  
11 respect to the pressure in the reservoir 413 (held  
12 about equal to ambient pressure in the borehole by  
13 means of a pressure-balancing floating annular piston  
14 (not shown) located between the shaft 432 and the  
15 support 450 to define one end of the reservoir 413).

16

17 Not shown in Fig 8 is a calibrated bleed which couples  
18 the relatively high pressure gallery 490 to the  
19 relatively low pressure reservoir 413 such that there  
20 is a sustained leak of hydraulic fluid from the high  
21 pressure side of the pump 405 to the low pressure side  
22 of the pump 405, the rate of leakage being  
23 substantially predetermined and preferably adjustable.  
24 The function of this leak is to de-pressurise the  
25 gallery 490 when the output of the pump 405 is low or  
26 zero, ie when the shaft 432 is turning slowly or is  
27 stationary with respect to the body of the support 450.  
28 However, the bleed is selected to be such that when the  
29 shaft 432 is rotating relatively rapidly with respect  
30 to the support 450 whereby the volumetric output of the  
31 pump 405 is relatively high, the leakage of the bleed  
32 is insufficient to drain the entire output of the pump  
33 405 and pressure builds up on the gallery 490.

34

35 When it is desired to extend the grip pads 401 in order  
36 temporarily to anchor the further support 450 to a

1 previously drilled wellbore (not indicated in Fig 8),  
2 the rotational speed of the shaft 432 with respect to  
3 the support 450 is increased from standstill or a very  
4 low rotational speed, up to a relatively high speed at  
5 which the volumetric output of the pump 405  
6 sufficiently exceeds the volumetric leakage rate of the  
7 above-described pressure bleed that pressure builds up  
8 in the gallery 490, such that the pistons (not shown in  
9 Fig 8) between the gallery 490 and the grip pads 401  
10 are forced radially outwards with respect to the  
11 longitudinal axis of the stabiliser 406, eventually to  
12 cause the grip pads 401 to contact the wellbore and  
13 anchor the stabiliser 406 at that location.

14

15 When it is desired to retract the grip pads 401 from  
16 their wellbore-contacting extended positions to  
17 respective radially inwards positions so as to de-  
18 anchor the stabiliser 406, it is sufficient to reduce  
19 the rotational speed of the shaft 432 by a suitable  
20 amount, eg by bringing the shaft 432 to a standstill.  
21 Shaft speed reduction reduces the output of the pump  
22 405 below the level at which the pump output is  
23 adequate to overcome losses through the calibrated  
24 bleed, and consequently the gallery 490 depressurises  
25 through the bleed. This depressurisation reduces and  
26 eventually substantially eliminates pad-extending force  
27 from the pad-extending pistons, allowing the pads 401  
28 to retract radially inwards into the support 450. Pad  
29 retraction is preferably assisted by springs (not shown  
30 in Fig 8) which are arranged to exert radially inwardly  
31 directed forces on each of the pads 401.

32

33 As an alternative to use of the above-described  
34 controlled bleed in conjunction with slowing or  
35 stopping rotation of the shaft 432 in order to retract  
36 the grip pads 401 from their wellbore-contacting

1 extended positions to respective radially inwards  
2 positions so as to de-anchor the stabiliser 406, the  
3 controlled bleed may be replaced by a  
4 remotely-controllable valve (not shown in Fig. 8) which  
5 couples the gallery 490 to the reservoir 413. The  
6 remotely-controllable valve may (for example) be a  
7 solenoid valve or any other suitable form of valve  
8 whose ability to pass or block the flow of fluid can be  
9 selectively controlled from a distance, eg from the  
10 surface installation at the top of the well. Closing  
11 of the remotely-controllable valve while the shaft 432  
12 is rotating will allow the pump 405 to pressurise the  
13 gallery 490 and so to extend the grip pads 401.  
14 Opening of the remotely-controllable valve (with or  
15 without slowing or stopping rotation of the shaft 432)  
16 will dump pressure from the gallery 490 to the  
17 reservoir 413, thereby allowing the grip pads 401 to  
18 retract radially inwards from the wellbore. Use of the  
19 remotely-controllable valve instead of the controlled  
20 bleed requires the addition of a control link to the  
21 surface (or other valve-controlling location) but has  
22 the advantage that rotation of the shaft 432 can be  
23 continued during retraction of the grip pads 401.  
24  
25 Although only one pump-containing bore 482 is shown in  
26 Fig 8, a plurality of such piston pump units could be  
27 provided, each in its respective bore  
28 (circumferentially distributed around the support 450  
29 in axial alignment with the eccentric ring 407 which  
30 radially reciprocates the respective piston of each  
31 such pump unit). The pump 405, the safety valve 498,  
32 and the calibrated bleed are conveniently housed within  
33 the greater radial extent of the upper-end shoulders of  
34 the three blades of the stabiliser 406 (which has an  
35 overall arrangement similar to that of the stabiliser  
36 206 as shown in Fig 7).

1 Referring now to Figs 9 and 10, Fig 9 is a longitudinal  
2 section of a preferred embodiment form of a stabiliser  
3 606 which is generally similar to the stabiliser 406 of  
4 Fig 8 (but incorporating certain detail differences  
5 which will be described below), the stabiliser 406 of  
6 Fig 8 being part of a directional drilling alignment  
7 assembly (not shown in the drawings) in the same manner  
8 that the stabiliser 206 of Fig 5A is part of the  
9 directional drilling alignment assembly 200 of Fig 4A.  
10 Fig 10 shows a transverse cross-section of the main  
11 body of the stabiliser 606, and will be detailed  
12 subsequently. The reference numerals which are applied  
13 to the components illustrated in Figs 9 and 10 are  
14 based on the reference numerals applied to the  
15 components illustrated in Fig 8 in the same way that  
16 the Fig 8 reference numerals are based on those of  
17 preceding Figs.

18  
19 In view of the many similarities of the stabiliser 606  
20 to the stabiliser 406, the following description of Fig  
21 9 will concentrate on those parts of the stabiliser 606  
22 which differ significantly from the stabiliser 406.  
23 (Operation of the stabiliser 606 is substantially  
24 identical to operation of the stabiliser 406).

25  
26 In the stabiliser 606 as illustrated in Fig 9, the  
27 pressure-limiting safety valve 698 is transferred from  
28 the housing 697 to the side bore 686. (The side bore  
29 687 is simply a through passage for hydraulic fluid).  
30 The housing 697 is devoid of internal passages (in  
31 contrast to the housing 497), with hydraulic fluid  
32 flowing around the solid housing 697 by way of a  
33 portion of the bore 683 (in which the housing 697 is  
34 mounted and sealed) having a local diameter somewhat  
35 larger than the local diameter of the housing 697.

36

1 Although only two grip pads 601 are shown in Fig 9,  
2 there are in fact three such grip pads, each mounted in  
3 a respective one of three symmetrically arranged  
4 stabiliser blades 651, as shown in Fig 10 (compare Fig  
5 10 with Fig 7). In this respect, Fig 9 is actually a  
6 section in two planes at 120° to one another, being  
7 shown as an apparent (but false) flat section for  
8 convenience and clarity.

9

10 Fig 10 shows a transverse cross-section of the  
11 stabiliser body 650, minus all other components. The  
12 grip pads 601 are each of an inverted T shape (in the  
13 radially outward direction) with side flanges (not  
14 shown) which fit in side grooves 652 formed in each of  
15 the longitudinally elongated slots 653 cut out of the  
16 blades 651 to accommodate the grip pads 601. These  
17 side flanges have a thickness in the radial direction  
18 (when assembled into a complete stabiliser 606) that is  
19 sufficiently less than the radial depth of the side  
20 grooves 652 as to allow the grip pads 601 to move  
21 radially in and out of the slots 652 between their  
22 fully retracted and fully extended positions.

23

24 The grip pads 601 are fitted in the slots 653 by being  
25 slid longitudinally into the slots 653 via cut-away  
26 lower ends of the blades 651. The fitted grip pads 601  
27 are retained, and the cut-away lower ends of the blades  
28 651 are restored, by means of suitably shaped retainers  
29 654 (Fig 9) fastened to the stabiliser body 650.

30

31 Springs (not shown) are preferably fitted to link the  
32 grip pads 601 and the stabiliser body 650 in a manner  
33 which urges the grip pads 601 radially inwards to their  
34 respective retracted positions when the pad-extending  
35 pistons 603 are not pressurised on their radially  
36 inwards sides by delivery from the pump 605 via the

1 pressure gallery 690. Such springs could take the form  
2 of corrugated strips of spring steel (not shown)  
3 located between the radially outer faces of the side  
4 flanges on the grip pads 601 and the radially outer  
5 sides of the side grooves 652, the side grooves being  
6 dimensioned to accommodate such springs in addition to  
7 the thickness (in the radial direction) of the grip pad  
8 side flanges plus the clearance necessary to allow full  
9 radial movement of the grip pads 601 between their  
10 fully retracted and fully extended positions.

11

12 The stabiliser 606 is utilised in a directional  
13 drilling alignment assembly 600 generally similar to  
14 the assembly 200 as shown in Figs 4A and 5, the  
15 assembly 600 incorporating the stabiliser 606 being  
16 partially illustrated in Fig 11 (corresponding to the  
17 central part of Fig 4A, with the right half of Fig 11  
18 corresponding to Fig 5).

19

20 The outer components of the stabiliser 606 are shown in  
21 section in Fig 12 (which is a bi-planar section in the  
22 same convention as Fig 9), and in plan in Fig 13  
23 (wherein the grip pads 601 are omitted in order to show  
24 the interior of the pad-accommodating slots 653).

25

26 The alignment assembly 600 below the stabiliser 606  
27 (the left end as shown in Fig 11) is shown to an  
28 enlarged scale in Fig 14, with part of Fig 14 being  
29 shown to a further enlarged scale in Fig 14A.  
30 Particularly detailed in Fig 14A is the  
31 pressure-balancing annular piston 617 (compare Fig 14A  
32 with Fig 5B).

33

34 The alignment assembly 600 above the stabiliser 606  
35 (the right end as shown in Fig 11) is shown to an  
36 enlarged scale in Fig 15 (which generally corresponds

1 to the right part of Fig 5). The combined radial and  
2 axial thrust bearings in the Fig 15 sub-assembly are  
3 shown to an enlarged scale in Fig 15A in the form of a  
4 tapered roller bearing, while the separate radial and  
5 axial thrust bearings (together with a seal assembly)  
6 are shown to an enlarged scale in Fig 15B in the form  
7 of single-row roller bearings.

8

9 While certain alternatives, modifications and  
10 variations have been described above, the invention is  
11 not restricted thereto, and other alternatives,  
12 modifications, and variations can be adopted without  
13 departing from the scope of the invention as defined in  
14 the appended Claims.

15

1        CLAIMS

2

3        1. A shaft alignment system (10;100;200) characterised by comprising a first shaft support means (12;112;212) having a first longitudinal axis (18) and a second shaft support means (14;114;214) having a second longitudinal axis (22;222), bearing means (127) rotatably coupling said first shaft support means (112) to said second shaft support means (114), said bearing means (127) having a bearing rotation axis, said bearing means (127) being arranged with respect to said first and second shaft support means (112,114) such that said bearing rotation axis is aligned at a first non-zero angle (18-40) with respect to said first longitudinal axis (18) and at a second non-zero angle (22-40) with respect to said second longitudinal axis (22) whereby relative rotation of said first and second shaft support means (12,14) about their respective longitudinal axes (18,22) varies the relative angular alignment of said first and second longitudinal axes (18,22).

22

23        2. A system (100) as claimed in Claim 1 characterised in that said first and second shaft support means (112,114) and said bearing means (127) are mutually disposed such that said bearing rotation axis intersects each of said first and second longitudinal axes.

29

30        3. A system (10) as claimed in Claim 2 characterised in that said first and second shaft support means (12,14) and said bearing means are mutually disposed such that said first and second longitudinal axes (18,22) mutually intersect.

35

36        4. A system (10;100;200) as claimed in any preceding

1      Claim characterised in that said first and second non-  
2      zero angles are selected from angles in the range of  
3      1°-3°.

4

5      5. A system (10;100;200) as claimed in any preceding  
6      Claim characterised in that said first and second  
7      non-zero angles are selected to be mutually equal  
8      whereby in one relative rotational position of the  
9      first and second shaft support means  
10     (12,14;112,114;212,214) said first and second  
11     longitudinal axes are mutually parallel.

12

13     6. A system (10;100) as claimed in any preceding  
14     Claim characterised in that said first shaft support  
15     means (12;112) comprises a first shaft bearing means  
16     (16) for supporting a shaft (34;132) for rotation about  
17     a first shaft rotation axis (18) coaxial with said  
18     first longitudinal axis (18) in the vicinity of said  
19     first shaft bearing means (16) and said second shaft  
20     support means (14;114) comprises a second shaft bearing  
21     means (20) for supporting a shaft (36;132) for rotation  
22     about a second shaft rotation axis (22;222) coaxial  
23     with said second longitudinal axis (22;222) in the  
24     vicinity of said second shaft bearing means (20).

25

26     7. An alignable shaft assembly (10;100;200)  
27     characterised by comprising the combination of a  
28     rotatable shaft means (32;132;232) and a shaft  
29     alignment system (10;100;200) as claimed in Claim 6,  
30     said shaft means (32) being rotatably supported by said  
31     first shaft bearing means (16) at a first region (34)  
32     along the length of the shaft means (32), said shaft  
33     means (32) being rotatably supported by said second  
34     shaft bearing means (20) at a second region (36) along  
35     the length of the shaft means (32), said shaft means  
36     (32) being constructed or adapted (38) for the

1 transmission of rotation between said first and second  
2 regions (34,36) in the range of relative alignments of  
3 the first and second shaft support means (12,14).

4  
5 8. An assembly (100) as claimed in Claim 7  
6 characterised in that said shaft means (132) is  
7 constructed or adapted for the transmission of rotation  
8 between said first and second regions by being formed  
9 as a flexible shaft (132) at least between said first  
10 and second regions.

11  
12 9. As assembly (10) as claimed in Claim 7  
13 characterised in that said shaft means (32) is  
14 constructed or adapted for the transmission of rotation  
15 between said first and second regions (34,36) by the  
16 provision between said first and second regions (34,36)  
17 of a shaft coupling means (38) mutually coupling said  
18 first and second regions (34,36) for conjoint rotation.

19  
20 10. An assembly (10) as claimed in Claim 9  
21 characterised in that said shaft coupling means (38) is  
22 a universal joint, for example a Hooke joint (38), or a  
23 constant-velocity joint, for example a Rzeppa joint.

24  
25 11. A system (10) as claimed in any of Claims 1 to 6,  
26 or an assembly (100) as claimed in any of Claims 7 to  
27 10 characterised in that the shaft alignment system  
28 (100) is provided with relative rotation control means  
29 (190) mutually coupling said first and second shaft  
30 support means (112,114) for controllably effecting  
31 relative rotation of said first and second shaft  
32 support means (112,114).

33  
34 12. A system or assembly (100) as claimed in Claim 11  
35 characterised in that said relative rotation control  
36 means (190) comprises non-reversible gear means (162)

1       mutually coupling said first and second shaft support  
2       means (112,114), and controllable drive means (180)  
3       coupled to the gear means (162) for imparting  
4       controlled relative rotation to said first and second  
5       shaft support means (112,114).

6

7       13. A system or assembly (100) as claimed in Claim 12  
8       characterised in that the gear means comprises a  
9       harmonic gearbox (162).

10

11       14. An assembly (100) as claimed in Claim 12 or in  
12       Claim 13 as directly or indirectly dependent on any of  
13       Claims 7 to 10 characterised in that the controllable  
14       drive means (180) is such as controllably to tap  
15       rotational power from the shaft means (132), for  
16       example, by way of a controllable clutch (180).

17

18       15. A system or assembly (100;200) as claimed in any  
19       preceding Claim and characterised by further comprising  
20       a further support means (150) having a respective  
21       further longitudinal axis, and further bearing means  
22       (152) having a respective further bearing axis, said  
23       further bearing means rotatably coupling said first  
24       shaft support means (112) to said further support means  
25       (150), said further bearing means (152) being arranged  
26       with respect to said first and further support means  
27       (112,150) such that said first and further longitudinal  
28       axes are mutually coaxial and also coaxial with said  
29       further bearing axis, whereby controlled rotation of  
30       said first support means (112) with respect to said  
31       further support means (150) results in control of the  
32       direction in which the second longitudinal axis  
33       deviates from the direction of the first longitudinal  
34       axis when the second shaft support means (114) is  
35       rotated with respect to said first shaft support means  
36       (112).

1 16. A system or assembly (100) as claimed in Claim 15  
2 characterised in that a further relative rotation  
3 control means (160) is provided and disposed mutually  
4 to couple said first and further support means  
5 (112,150) for controllably effecting relative rotation  
6 of said first and further support means (112,150).

7

8 17. A system or assembly (100) as claimed in Claim 16  
9 characterised in that said further relative rotation  
10 control means (160) is substantially identical to the  
11 first said relative rotation control means (190).

12

13 18. A directional drilling alignment assembly (200)  
14 for controllably aligning the downhole end (214) of a  
15 drillstring to enable directional drilling of a well in  
16 geological formations, said alignment assembly (200)  
17 comprising an alignable shaft assembly (200) as claimed  
18 in any of Claims 7 to 14 together with a further  
19 support means (250) as claimed in Claim 15 or in Claim  
20 16, characterised in that said further support means  
21 (250) is provided with bore anchorage means (206) for  
22 selectively temporarily anchoring said further support  
23 means (250) to a previously drilled bore whereby  
24 controlled rotations of said first shaft support means  
25 (212) with respect to said further support means (250)  
26 and of said second shaft support means (214) with  
27 respect to said first shaft support means (212) enable  
28 selective variation (with respect to said previously  
29 drilled bore in which said further support means is  
30 temporarily anchored) of both the direction (bearing)  
31 and angular extent of deviation of the shaft means  
32 (232) in said second shaft support means (214) and  
33 hence of an extension of the bore to be drilled by a  
34 bit (204) on the downhole end (214) of said shaft  
35 means.

36

1       19. A directional drilling alignment assembly (200) as  
2       claimed in Claim 18 and characterised by further  
3       comprising an azimuth sensor or other direction sensing  
4       means fixed with respect to said further support means  
5       (250) and operative at least when said bore anchorage  
6       means (206) is operative to sense the direction  
7       (bearing) of the further support means (250) when  
8       anchored whereby to determine such further deviation as  
9       may be necessary or desirable in order for the drill  
10      (204) to proceed in a particular direction (222).

11

12      20. A method of directional drilling, said method  
13      being characterised by comprising the steps of  
14      providing a directional drilling alignment assembly  
15      (200) as claimed in Claim 18 or in Claim 19, securing a  
16      drill bit (204) on the remote end (214) of said shaft  
17      means (232) and deploying said alignment assembly (200)  
18      on the downhole end of a drillstring in a previously  
19      drilled bore, temporarily anchoring the further support  
20      means of said alignment assembly in said previously  
21      drilled bore, sensing the direction (bearing) of said  
22      temporarily anchored further support means (250),  
23      rotating said first shaft support means (212) with  
24      respect to said further support means (250) and/or  
25      rotating said second shaft support means (214) with  
26      respect to said first shaft support means (212) until  
27      the rotation axis (222) of the drill bit (204) is  
28      aligned in a selected direction, and continuing  
29      drilling.

30

31      21. A shaft alignment system substantially as  
32      hereinbefore described with reference to and as shown  
33      in the accompanying drawings.

34

35      22. An alignable shaft assembly substantially as  
36      hereinbefore described with reference to and as shown

1 in the accompanying drawings.

2

3 23. A directional drilling alignment assembly

4 substantially as hereinbefore described with reference

5 to and as shown in the accompanying drawings.

6

7 24. A directional drilling alignment assembly as

8 claimed in Claim 23, in combination with bore anchorage

9 means substantially as hereinbefore described with

10 reference to and as shown in Figs 5 and 5A, or Fig 8,

11 or Figs 9, 10, 11, 12 and 13 of the accompanying

12 drawings.

13

14 25. A method of direction drilling utilising a

15 directional drilling alignment assembly as claimed in

16 Claim 23 or in Claim 24, substantially as hereinbefore

17 described.



Application No: GB 9624103.9  
Claims searched: 1 - 25

Examiner: C J Duff  
Date of search: 3 February 1997

**Patents Act 1977**  
**Search Report under Section 17**

**Databases searched:**

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK CI (Ed.O): E1F(FCU), F2U

Int CI (Ed.6): E21B 7/06, 7/08, F16D 3/02, 3/16, 3/84

Other: On-line: WPI

**Documents considered to be relevant:**

Category	Identity of document and relevant passage		Relevant to claims
X	GB 1494273	(RUSSELL) Whole document	1 - 5
A, P	US 5495900	(FALGOUT) Whole document	
A	US 4694914	(OBRECHT) Whole document	

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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